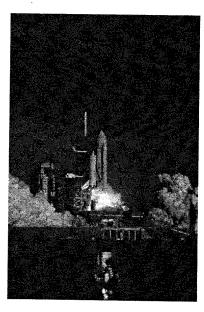
Appendix A

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Kapton^e is used in applications such as the solar array and for thermal management in the United States space program.



General Information

Kapton® polyimide film possesses a unique combination of properties that make it ideal for a variety of applications in many different industries. The ability of Kapton® to maintain its excellent physical, electrical, and mechanical properties over a wide temperature range has opened new design and application areas to plastic films.

Kapton® is synthesized by polymerizing an aromatic dianhydride and an aromatic diamine. It has excellent chemical resistance; there are no known organic solvents for the film. Kapton® does not melt or burn as it has the highest UL-94 flammability rating: V-0. The outstanding properties of Kapton® permit it to be used at both high and low temperature extremes where other organic polymeric materials would not be functional.

Adhesives are available for bonding Kapton® to itself and to metals, various paper types, and other films.

Kapton® polyimide film can be used in a variety of electrical and electronic insulation applications: wire and cable tapes, formed coil insulation, substrates for flexible printed circuits, motor slot liners, magnet wire insulation, transformer and capacitor insulation, magnetic and pressure-sensitive tapes, and tubing. Many of these applications are based on the excellent balance of electrical, thermal, mechanical, physical, and chemical properties of Kapton® over a wide range of temperatures. It is this combination of useful properties at temperature extremes that makes Kapton® a unique industrial material.

Three types of Kapton® are described in this bulletin:

 Kapton® Type HN, all-polyimide film, has been used successfully in applications at temperatures as low as -269°C (-452°F) and as high as 400°C (752°F). Type HN film can be laminated, metallized, punched, formed, or adhesive coated. It is available as 7.5 μ m (0.3 mil), 12.5 μ m (0.5 mil), 19 μ m (0.75 mil), 25 μ m (1 mil), 50 μ m (2 mil), 75 μ m (3 mil), and 125 μ m (5 mil) films.

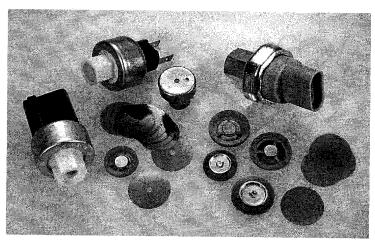
- Kapton® Type VN, all-polyimide film with all of the properties of Type HN, plus superior dimensional stability. Type VN is available as 12.5 μm (0.5 mil), 19 μm (0.75 mil), 25 μm (1 mil), 50 μm (2 mil), 75 μm (3 mil), and 125 μm (5 mil) films.
- Kapton® Type FN, a Type HN film coated on one or both sides with Teflon® FEP fluoropolymer resin, imparts heat sealability, provides a moisture barrier, and enhances chemical resistance. Type FN is available in a number of combinations of polyimide and Teflon® FEP thicknesses (see **Table 16**).

Note: In addition to these three types of Kapton®, films are available with the following attributes:

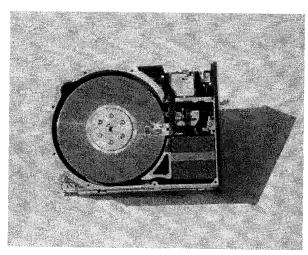
- · antistat
- thermally conductive
- · polyimides for fine line circuitry
- cryogenic insulation
- corona resistant
- · pigmented for color
- conformable
- other films tailored to meet customers' needs

Data for these films are covered in separate product bulletins, which can be obtained from your DuPont representative.

The Chemical Abstracts Service Registry Number for Kapton® polyimide film is [25036-53-7].



Kapton $^\circ$ withstands the harsh chemical and physical demands on diaphragms used in automotive switches.



Kapton $^{\rm e}$ is used in numerous electronic applications, including hard disk drives.

Physical and Thermal Properties

Kapton® polyimide films retain their physical properties over a wide temperature range. They have been used in field applications where the environmental temperatures were as low as -269°C (-452°F) and as high as 400°C (752°F).

Complete data are not available at these extreme conditions, and the majority of technical data presented in this section falls in the 23 to 200°C (73 to 392°F) range.

Table 1 Physical Properties of Kapton® Type 100 HN Film, 25 μ m (1 mil)

Discount Promotes		Value at	
Physical Property	23°C (73°F)	200°C (392°F)	Test Method
Ultimate Tensile Strength, MPa (psi)	231 (33,500)	139 (20,000)	ASTM D-882-91, Method A*
Yield Point at 3%, MPa (psi)	69 (10,000)	41 (6000)	ASTM D-882-91
Stress to Produce 5% Elongation, MPa (psi)	90 (13,000)	61 (9000)	ASTM D-882-91
Ultimate Elongation, %	72	83	ASTM D-882-91
Tensile Modulus, GPa (psi)	2.5 (370,000)	2.0 (290,000)	ASTM D-882-91
Impact Strength, N.cm (ft-lb)	78 (0.58)		DuPont Pneumatic Impact Test
Folding Endurance (MIT), cycles	285,000		ASTM D-2176-89
Tear Strength—Propagating (Elmendorf), N (lbf)	0.07 (0.02)		ASTM D-1922-89
Tear Strength—Initial (Graves), N (lbf)	7.2 (1.6)		ASTM D-1004-90
Density, g/cc or g/mL	1.42		ASTM D-1505-90
Coefficient of Friction—Kinetic (Film-to-Film)	0.48		ASTM D-1894-90
Coefficient of Friction—Static (Film-to-Film)	0.63		ASTM D-1894-90
Refractive Index (Sodium D Line)	1.70		ASTM D-542-90
Poisson's Ratio	0.34		Avg. Three Samples Elongated at 5%, 7%, 10%
Low Temperature Flex Life	Pass		IPC TM 650, Method 2.6.18

^{*}Specimen Size: 25×150 mm (1 × 6 in); Jaw Separation: 100 mm (4 in); Jaw Speed: 50 mm/min (2 in/min); Ultimate refers to the tensile strength and elongation measured at break.

Table 2
Thermal Properties of Kapton® Type 100 HN Film, 25 μm (1 mil)

Thermal Property	Typical Value	Test Condition	Test Method
Melting Point	None	None	ASTM E-794-85 (1989)
Thermal Coefficient of Linear Expansion	20 ppm/°C (11 ppm/°F)	-14 to 38°C (7 to 100°F)	ASTM D-696-91
Coefficient of Thermal Conductivit W/m K cal	y, 0.12	296 K	ASTM F-433-77 (1987) ^{∈1}
cm·sec·°C	2.87 × 10 ⁻⁴	23°C	
Specific Heat, J/g·K (cal/g·°C)	1.09 (0.261)		Differential Calorimetry
Flammability	94V-0		UL-94 (2-8-85)
Shrinkage, %	0.17 1.25	30 min at 150°C 120 min at 400°C	IPC TM 650, Method 2.2.4A ASTM D-5214-91
Heat Sealability	Not Heat Sealable		
Limiting Oxygen Index, %	37		ASTM D-2863-87
Solder Float	Pass		IPC TM 650, Method 2.4.13A
Smoke Generation	DM = <1	NBS Smoke Chamber	NFPA-258
Glass Transition Temperature (T ₉)	and is assumed to b	e the glass transition tem	etween 360°C (680°F) and 410°C (770° perature. Different measurement e above temperature range.

Appendix B

Polyimide PI

Click here to return to materials

Find products containing this material in the following

Αll

Search

Common Brand Names:

Kapton, Kinel, Upilex, Upimol, Vespel

General Description:

General Description: Normally infusible, coloured (often amber) high performance polymers with predominantly aromatic molecules of high thermal stability. Semi-fabricated shapes are usually supplied by the polymer manufacturer and made by powder sintering or working with more tractable pre-cursors and completing polymerisation in final form, though some melt-processable grades of resin are manufactured. They have excellent high temperature properties and radiation resistance, inherently low flammability and smoke emission, low creep and high wear resistance and are very expensive. They have moderately high water absorption and are prone to hydrolysis and attack by alkalis and concentrated acids.

A widely used form is Kapton® film, made in thicknesses from 0.008 to 0.125mm and which is a transparent amber colour. Thicker polyimide items are usually opaque. A range of Kapton film variants are also available. In each of these, a large measure of Kapton's basic properties are combined with an extra attribute eg increased electrical or thermal conductivity, improved corona resistance, opacity and thermoplasticity.

Films are used for capacitators, insulation, printed circuit boards and in aerospace; other applications include engine components, bearings and mechanical parts exposed to radiation.

Explanation of Kapton grade descriptions

HN Regular Kapton - Transparent Amber

CB Opaque black version of HN

 $\boldsymbol{\mathsf{MT}}$ Aluminium oxide filled, increased thermal conductivity, opaque yellow

MTB Opaque black version of MT

CR Improved corona resistance - translucent yellow

XC Electrically (semi-)conductive - opaque black

KJ Thermoplastic - transparent yellow

Chemical Resistance Acids - concentrated

Poor

A.N.A. District	
Acids - dilute	Fair
Alcohols	Poor
Alkalis	Poor
Aromatic hydrocarbons	Good
Greases and Oils	Good
Halogenated Hydrocarbons	Good
Halogens	Fair
Ketones	Good
Electrical Properties	
Dielectric constant @1MHz	3.4
Dielectric strength (kV mm ⁻¹)	22
Dissipation factor @ 1kHz	
Surface resistivity (Ohm/sq)	0.0018
	10 ¹⁶
Volume resistivity (Ohmcm)	10 ¹⁸
Mechanical Properties	
Coefficient of friction	0.43
Elongation at break (%)	0.42 8-70
Hardness - Rockwell	- · ·
Izod impact strength (] m ⁻¹)	E52-99
Tensile modulus (GPa)	80
Tensile strength (MPa)	2.0-3.0
rensile strength (MFa)	70-150
Physical Properties	
Density (g cm ⁻³)	1.42
Flammability	V0
Limiting oxygen index (%)	53
Radiation resistance	Good
Refractive index	1.66
Resistance to Ultra-violet	Poor
Water absorption - over 24 hours (%)	0.2-2.9
Thermal Properties	
•	
Coefficient of thermal expansion (x10 ⁻⁶ K ⁻¹)	30-60
Heat-deflection temperature - 1.8MPa (C)	360
Lower working temperature (C)	-270
Specific heat ($J K^{-1} kg^{-1}$)	1090
Thermal conductivity (W m ⁻¹ K ⁻¹)	0.10-0.35 @ 23C
Upper working temperature (C)	250-320
	·

Properties Polyimide Film

Property		Value				
Material Coefficient of thermal expansion	×10 ⁻⁶ K ⁻¹	HN 20	СВ	MT	МТВ	CR
Corona Resistance @ 20kV mm ⁻¹ 50 Hz	hr	200				>100,
Density Dielectric Constant @ 1MHz	g cm ⁻³	1.42 3.4	1.42	1.85	1.85	1.54
Dielectric Constant @ 1kHz Dielectric Strength @25µm thick Dissipation Factor @1MHz	kV mm ⁻¹	3.4 300 0.01	4.5 80	4.2 165	4.2 70 @ 0.075mm	3.9 290
Dissipation Factor @1kHz Elongation at Break	%	0.0018 70	0.19 45	50-60	50-60	0.003 45

Initial Tear Strength	g µm ⁻¹	20				
Moisture absorption	%	2.8		3	3	
Permeability to Carbon Dioxide @25C	${\rm x}10^{-13}~{\rm cm}^3$. cm cm ⁻² s ⁻¹ Pa ⁻¹	0.5				
Permeability to Hydrogen @25C	$x10^{-13}$ cm ³ , cm cm ⁻² s ⁻¹ Pa ⁻¹	1				
Permeability to Nitrogen @25C	$\times 10^{-13} \text{ cm}^3$. cm cm ⁻² s ⁻¹ Pa ⁻¹	0.03				
Permeability to Oxygen @25C	$\times 10^{-13} \text{ cm}^3$. cm cm ⁻² s ⁻¹ Pa ⁻¹	0.1				
Permeability to Water @25C	$x10^{-13}$ cm ³ . cm cm ⁻² s ⁻¹ Pa ⁻¹	400				
Permeability to Water @38C	$x10^{-13}$ cm ³ . cm cm ⁻² s ⁻¹ Pa ⁻¹	500				
Shrinkage @400C	%	1.2-1.5	1	1	1	0.6
Surface Resistivity	Ohm/sq			-	***	3.6x1(
Tensile modulus	GPa	2.5	2.7	4	4	3.0
Tensile strength	MPa	230	135	125	125	150
Thermal Conductivity @23C	$W m^{-1} K^{-1}$	0.16		0.45	0.45	0.38
Volume Resistivity	Ohmcm	1.5x10 ¹⁷	10 ¹³	10 ¹⁴	10 ¹⁴	2.3x1(

Properties Polyimide Chopped Fibre

Property		Value
Specific Tenacity	cN/tex	38
Extension to break	%	30
Limiting Oxygen Index	%	38
Shrinkage @180C	%	<1
Tenacity	GPa	540

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Appendix C

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Resources, Tools and Basic Information for Engineering and Design of Technical Applications!

Thermal Conductivity of some common Materials

Thermal conductivity of some common materials as aluminum, asphalt, brass, copper, steel and many more

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Thermal conductivity is the quantity of heat transmitted through a unit thickness in a direction normal to a surface of unit area, due to a unit temperature gradient under steady state conditions.

Thermal conductivity, or heat transfer coefficients, of some common materials and products can be found in the table below:

Material/Substance	Temperature (°C)				
	25	125	225		
Acetone	0.16	and and the second superior control to the second superior of the second superior su			
Acrylic	0.2	and approximate the second	September of the section of the sect		
Air	0.024	Andrewson with the second of t	To the second se		
Alcohol	0.17		Control of the Contro		
Aluminum	250	255	250		
Aluminum Oxide	30	State (Colon de la colonia y communica de la colonia d			
Ammonia	0.022	eller om skriver det som i known i de myd foder delleren freken og eller skriver om det som i de en en genger	-		
Antimony	18.5	energia de la companie de la companie de Angelen (de Parente de La companie de la	dateban en essa suprangant, esta esperandante.		
Argon	0.016	an and a second of the second data and an entered the second of the second data and the second of the analysis			
Asbestos-cement board	0.744	ti etti ola taa toodan taasa maassa satti tootaa ettää tävittää täytää täytää taasaa satta tootaa sattii toota			
Asbestos-cement sheets	0.166	and the second s	and the second s		
Asbestos-cement	2.07		and the description of the section o		
Asbestos, loosely packed	0.15		a en		
Asbestos mill board	0.14	The same and the same of the s	and the street of the street o		
Asphalt	0.75		- Company of the Sagar Super State of the Sagar Super		
Balsa	0.048	enteror state (E.). Est and according to the control of the section of the control of the contr			
Bitumen	0.17				
Benzene	0.16	P. Parkinaninka ang agunonah en mananin a samannan an ang mananin ang manggan ang ang manggan ang ang agunong Banggan ang ang agunong ang agunonah ang	NAPARAMANANA PARAMANANA PA		
Beryllium	218	TO COMPANY OF THE PROPERTY OF			
Brass	109	del de artigo en estado en como de contrato en estado en estado en el como de entre en estado en estado en esta	Canada and the same about a transportation and		
Brick dense	1.31	en hanne describer in de l'en man describer del gelocole de la 1970 de l'application de l'application de l'app	Martin di Printe ni Salambara di Assistanti di Salambara (Sanggara) per manya		
Brick work	0.69		**************************************		
Cadmium	92		namen and the second se		
Carbon	1.7		**************************************		
Cement, portland	0.29	- management of the management of the second and an action of the second and action of the second acti			
Cement, mortar	1.73	facility commences and the second commences and the second commences are seco	National Communication Subsequences or Company or Communication (Communication Communication Communi		
Chalk	0.09	New distance in the season of the section of the se	Production and which delical being agreement and production of the		
Cobalt	69	englines propagation of territorial type of reprint and an advance and accompany	Contraction of the contraction of the second of the		

onductivity of some common M	laterials		
Concrete, light	0.42		
Concrete, stone	1.7		
Constantan	22		
Copper	401	400	398
Corian (ceramic filled)	1.06		000
Corkboard	0.043		
Cork, regranulated	0.044		
Cork, ground	0.043		
Cotton	0.03		
Carbon Steel	54	51	A"7
Cotton Wool insulation	0.029	31	47
Diatomaceous earth (Sil-o-cel)	0.06		
Earth, dry	1.5		
Ether	0.14		
Ероху	0.35		
Felt insulation	0.04		
Fiberglass	0.04		
Fiber insulating board	0.048		·
Fiber hardboard	0.2		
Fireclay brick 500°C	1.4		
Foam Glass			
Gasoline	0.042		
Glass	0.15		
·	1.05		
Glass, Pearls, dry	0.18	•	
Glass, Pearls, saturated	0.76		
Class, window	0.96		
Glass, wool Insulation	0.04		
Glycerol	0.28		
Gold	310	312	310
Granite	1.7 - 4.0		٠
Gypsum or plaster board	0.17	4	•
Hairfelt	0.05		
Hardboard high density	0.15	•	
Hardwoods (oak, maple) Helium	0.16		
	0.142		
Hydrogen	0.168		
<u>lce</u> (0°C, 32°F)	2.18		
Insulation materials	0.035 - 0.16		2000
Iridium	147		3 3 8
Iron	80	68	60
Iron, wrought	59		24.00
Iron, cast	55	•	
Kapok insulation	0.034		
Kerosene	0.15		Cape
Lead Pb	35		00 miles
Leather, dry	0.14		
Limestone	1.26 - 1.33		9769976
Magnesia insulation (85%)	0.07		All Colonia
Magnesium	156		riger of general research
Marble	2.6		**************************************

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RF



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Thermal Conductivity & Coefficient of Expansiona

High Performance RF & **Microwave Catalog Products**

Substance	Thermal Conductivity (W/cm [,] °C)	Coefficient of Thermal Expansion (ppm/°C)	Density (g/cm ³)	Specific Thermal Conductivity ^b (W/cm·°C)
Air (still)	0.0003			(11,011,0)
Alumina	0.276		-	
Alumina (85%)	0.118			
Aluminum	2.165	0.23	2.7	0.81
Beryllia (99.5%)	1.969			0.01
Beryllia (97%)	1.575			
Beryllia (95%)	1.161			
Beryllium	1.772			
Beryllium-Copper	1.063			
Boron Nitride	0.394			
Brass (70/30)	1.220			
Copper	3.937	0.17	8.9	0.45
Copper/Inv ^c /Copper	1.64	0.084	8.4	.020
Copper/Mo ^d /Copper	1.82	0.060	9.9	
Copper/Mo ^d -Cu/Copper	2.45-2.80	0.60-0.10	9.4	0.18
Diamond (room temp)	6.299	0120	J.7	0.26-0.30
Ероху	0.002			
Epoxy (thermally conductive)	0.008			
FR-4 (G-10)	0.003			
GaAs	0.591			
Glass	0.008			·
Gold	2.913			
Heatsink Compound	0.004	*	-	
Helium (liquid)	0.000307			
Invar	0.11	0.013	8.1	0.044
Iron	0.669	0.013	0.1	0.014
Kovar	0.17	0.59	8.3	0.000
Lead	0.343	0.00	0.5	0.020
Magnesium	1.575			
Mica	0.007			
Molybdenum	1.299			
Monel	0.197			

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Mylar	0.002			
Nickel	0.906			
Nitrogen (liquid)	0.001411			
Phenolic	0.002			
Platinum	0.734			
Sapphire (a-axis)	0.32			
Sapphire (c-axis)	0.35			
Silicon (pure)	1.457			
Silicon (0.0025 Ω-cm)	1.457			· · · · · · · · · · · · · · · · · · ·
Silicon Carbide	0.90			
Silicon Dioxide (amorphous)	0.014			
Silicon Dioxide (quartz, a- axis)	0.059			
Silicon Dioxide (quartz, c- axis)	0.11			
Silicone Grease	0.002			
Silicone Rubber	0.002			
Silicon Nitride	0.16 - 0.33			
Silver	4.173			
Stainless Steel (321)	0.146			
Stainless Steel (410)	0.240			
Steel (low carbon)	0.669			
Teflon	0.002			
Tin	0.630			
Titanium	0.219	0.086	4,4	0.016
Tungsten	1.969			
Water	0.0055			
Zinc	1.024			

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Rf Publications Download free ic design technical papers today! www.mentor.com/dsm a: Approximate values from 0 °C to 100 °C

b: Thermal conductivity divided by specific gravity (introduced by Dr. Carl Zweben & K.A. Schmidt)

c: Invar

d: Molybdenum

